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INTRODUCTION TO THE ECONOMICS OF CONSTRUCTION MECHANIZATION

Condensed text of a candidate dissertation under the same title submitted to the Hungarian Academy of Sciences in Budapest in 1955. (One year before the Revolution.)

Translation from Hungarian

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1.0 Introduction

The outlays of construction industry represent the most considerable part of the investments used for the systematic increase of capital investments of the national economy. Whether the accumulations available for the national economy in a very limited quantity will serve the extended reproduction effectively and rapidly is mostly a function of the efficiency and method of the construction industry. Therefore it is highly important that a more profitable production would be made possible.

The mode of production in the socialism is planned economy and that is why a good knowledge of factors and their relations influencing the development of production is essential; the two latter representing the most important preliminary conditions for a fully conscious scientific planning. A successful planning of production has to be based on the analysis, evaluation and prediction of all factors of production especially the technical and economical parameters determining the process of production. The clue to a farsighted planning as well as to more scientific political economy is a continuous analysis of the process of production with the guidance of the economy of production.

The economical analysis of production can be done from the points of view of the outputs and the inputs. Output and input are not always considered as absolute magnitudes but often their comparison to each other and to other factors of production are taken into consideration.

Production - as every economic phenomenon is performed in the time and the time factor determines the production so much that actually production is understood as production per time;

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"speed of production". Moreover, only this concept can be defined as adequate for the purposes of economical analysis of production. The analysis of speed of production and related parameters is one of the most important research areas of economy of production.

The effect of time factor from the aspect of input is not of less importance, however, in this case there is a more important basis for comparison, the expression of input in function of output that is the category of cost. The magnitude and change of cost is another principal subject of economic analysis.

The above mentioned two complex fields of economic analysis include a multitude of related factors and their interrelations. Among those stress has to be laid on the composition of productive forces which is a foremost determining factor of the phenomonon of both mentioned fields of analysis. The composition of productive forces can be expressed by proportions of living labor and materialized labor in the cooperating means of production.

The instruments of labor for the modern production are machines. Now-~~of~~-days the degree of mechanization is accepted as the most characteristic parameter for the mode of production all over the world. Consequently the economic analysis of production has to be very particular about mechanization and the related technical and economical interrelations especially in those fields where the progress of mechanization that is the changes in the composition of productive forces was very rapid since a socialist industry has been established. As it is known (that) construction industry is the most typical one of these fields, mechanization has its effect on the speed of production and on the other hand it influences the magnitude and composition of input.

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Another establishment includes the well known thesis of socialism that mechanization substituting living labor exempts laborers from heavy work.

Therefore, the economy of mechanization and the related technical economical analysis has to be concerned with the question, how mechanization effects the speed of production and with the outlays made necessary by mechanization, i.e., with cost.

One former field the actual subject is the quantity of commodities produced in certain time intervals, generally speaking the output of mechanized production as subject and goal of analysis, thus the real task of analysis in this relation is to allocate the capacity of machines and the time.

The second field; the analysis of inputs of mechanization has two dimensions. The analysis has to cover the change of proportions of living labor input and the materialized labor input. The measure of living labor input is the working time, so the task is to analyse the allocation of working time connected with mechanization.

The analysis of materialized labor input is a complex problem. The summarized effect of numerous different factors has to be expressed by cost in money terms at the present stage of socialism. Consequently the economy of construction mechanization has to analyse with the assistance of technical economical analysis as a method of research - the effect of changes in the composition of productive forces caused by mechanization on the speed of production, productivity and costs in the construction industry.

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Construction industry is the one that enjoyed the largest scale and the most rapid progress in mechanization among all the branches of our industry since 1945. Unfortunately, however, the opportunities provided by mechanization have not been exploited successfully enough to the present day. The use of construction machinery acquired at great sacrifices did not contribute adequately to the decrease of cost of production and similarly failed to raise the productivity to a reasonably expectable level. Undoubtedly this was partly due to the fact that up to now the questions posed by the inter-action between output and mechanization in the construction industry, as well as the problem of complex economic interpretation of related factors and interrelations have been clarified only to a small degree.

There is a desperate need for a systematized knowledge of the most important economic principles and pertinent economic tools of analysis which are necessary in the evaluation of the economical character of mechanization. Our mechanization policy consequently did not always contribute to the economy at a maximum degree, besides the composition of our industry did not go through the changes required by the progressive changes in the composition of productive forces. Recently a great many spontaneous and often destructive symptoms and opinions appeared about mechanization.

It is indubitable that there exists an objective relation between mechanization and the goals of production set forth. The aim of this thesis is to present and summarize general laws effecting the use of construction machinery and to establish the most important theoretical and in practice realizable and adopt able relationships of the technical-economical process of

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mechanization, in order to render possible, by means of already existing or herewith obtained parameters certain conclusions relative to some of the guiding principles of the technical development of the relation between construction mechanization and the building industry.

2.0 The Performance of Construction Machines

Manual work is dominating yet at most of the construction and consequently the capacity of production at present is a function of the number of laborers available, but at some of the leading constructions and considering the perspective of progress, the effect of mechanized operations in the process of production is becoming more and more determining.

In order to be able to evaluate this effect we have to know which of the characteristics are the most significant aspects of aptness in the production.

By the application of construction machinery a certain quantity of products is produced during a given time interval. The quantity of products produced divided by the time consumed is equal to the output of machines.

The performance of the machines is not constant in time but it varies in function of same and it's magnitude depends on the time interval referred to. Consequently we will arrive to different values of performance of a machine when referring to the time of operation, to the whole duration of a construction or to a calendar year.

During a given interval, periods of operation and periods of pause can be distinguished. Referring to the operating time "t_{op}". The performance can be expressed:

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$$q_{op} = \frac{Q}{t_{op}}$$

Where q_{op} = quantity produced in the unit of time

Q = Total production

And referring to the Total time "T_t"

$$q_t = \frac{Q}{T_t}$$

But the quantity produced is independent from the time referred to.

Therefore

$$q_t = q_{op} \frac{t_{op}}{T_t}$$

Where

$\frac{t_{op}}{T_t}$ ratio is the index of extensive machine utilization denoted by "e".

The machine performance usually varies during the time of operation "q_{op}" may take different values. One of the q_o being the maximum attainable performance under the given technical circumstances. Therefore it is customary to express the actual performance in function of a prescribed performance where the quotiant indicates the intensive utilization of capacity denoted by "i".

$$\frac{q_{op}}{q_o} = i$$

The product "i.e" is called machine utilization denoted by "g". The machine utilization index "g" shows how the actual performance in a given time interval is related to the performance that could be achieved at full extensive and intensive utilization.

The preceeding paragraphs covered the method of standardization of the notion of measures of performance. The system of survey of

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performance and related collection of data however differs from this.

The main cause of the difference in comparison to above mentioned is that the time referred to is not the precisely definable machine operating time but the very uncertain running time. On the survey of machine performance the category of performance related to the running time can and has to be accepted so much the more that it is the only measurable time in connection with machines and also because the knowledge of running time is indispensable for other economical purposes such as tear and wear and fuel consumption.

The relation of the performance achieved during the running time q_r and the performance norm can be given as follows:

$$q_r = iq_o$$

In the construction industry the analyzed intervals of production cannot be confined only to the running time of machines. A knowledge of performance values of the whole duration of working time; namely the average performance of shift hours or working days is also essential. This measure will show the relation how the machines fit into the process of production as a whole.

The fit of the relation can be indicated by the index of extensive utilization. The actual indexes of extensive utilization can be expressed by several interpretations. The most handy and common of these is the practice of running hours and shift hours.

$$\frac{\text{Number of running hours}}{\text{Number of shift hours}} = \text{"e"}$$

The average performance of a machine during the shifts on the site can be given as follows:

$$q_a = e.iq_o$$

or introducing $e.i = g$

$$q_a = gq_o$$

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Where g is the index of machine utilization related to the duration of shifts.

"g" is the most important general utilization index namely the chief index of the coordination of the plant, of sound use of machines and indirectly of the efficiency of mechanization in aspect of decrease of cost and increase of productivity. This index indicates that to what extent the living labor employed in the production made use of the available materialized labor emobodied in the means of production. In this comprehension, however, usually not only the utilization of single machines but that of a whole set of machines has to be calculated. This problem raises the question of the summation of modern utilization indexes which can be done in two ways: a) by weighed means or , b) by arithmetical means. As it was pointed out above there is materialized labor embodied in the machine and the quantity of this labor is realized in their value (price). The most important and common property of the machines of all types and with all working conditions is this value. For the sake of economy of production it is necessary that we would allocate economically not only the living but the materialized labor as well. Therefore in summing up the utilization indexes the most important factor is the amount of materialized labor represented by the given index.

This weighed utilization index expresses in these terms the % of machine value assisting in the production - the so called active machine value would have been enough to accomplish the same production at 100% utilization.

It has to be noted that there is another weighing method used in the industry for similar purposes. This method uses the term of

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working power equivalent for the evaluation and weighing of machines as well (see later). In practice this method can also be used since machine value and its working power equivalent are in close relationship (but theoretically it is not correct).

3.0 The Factors of the Cost of Construction Mechanization.

3.1 The Set Up Cost of Construction Machines.

One of the most significant properties in which construction industry differs from manufacturing industry is that while in the latter the products are moving from machine to machine during the production, in the construction industry the building itself is not moving, but the tools (machines) have to change their places from building to building. This moving, the repeated setups of machines certainly cost money and these are indispensable factors of machine cost although it is very likely and a common mistake to be forgotten. The set up costs of the construction machines includes the following elements:

1. Cost of loading and unloading
2. Cost of transportation
3. Cost of mounting and dismounting on the site.

The set up cost is considered not as absolute amount but as specific cost per product unit for the purpose of machine cost calculations. The set up cost of a machine certainly burdens all the products that are produced on the site by the machine.

The total cost of set up (F) therefore burdens the total of products produced on the site "Q" hence the specific cost(f) related to the units of products is

$$f = \frac{F}{Q} \quad \text{Forint/ product unit.}$$

Which means that the specific set up cost is proportional with the

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inverse of the quantity of products produced on one site, i.e. with the inverse of the lot size.

The lot size of construction can be increased when the production of prefabricated elements is taken into consideration instead of the buildings themselves. Naturally the lot size also has an upper limit especially in the case of prefabrication. The larger the prefabricating plant is and the greater the area it serves with products, the higher the transportation cost of the products will be. Beyond a certain size of area served, or so to say a certain quantity of products, the total production cost will not be decreased in spite of the decrease in specific set up cost, moreover they will be increased.

Again it has to be noted that the planning methods of specific set up cost used in the practice of our industry make it difficult to evaluate numerically or practically the simple relations mentioned above. In the budgets the machine set up cost is not listed among the machine cost but with the other set up costs of the construction consequently the relation of machine cost to the products is substituted by the indissoluble relation of the total set up cost to the value of the construction.

Relating the machine set up costs and the value of the buildings this way is a ground for planning uneconomical mechanizations especially because the losely planned uncontrollable set up cost easily can be changed, moreover increasing them becomes an interest having their increasing effect on the price of construction.

Under such circumstances there is no opportunity to execute any conscious action in the practice of mechanization policy toward the goals of diminishing machine set up cost. There is another

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regrettable fact to be pointed out about this matter that under the present and above described circumstances the actual or proper magnitude of the specific machine set up cost is unknown before those in charge moreover it's numerical value is not even being studied.

3.2 The Reproduction Cost of Construction Machines.

The instruments of labor used in the construction industry are construction machines in increasing number. The instruments of labor themselves are also products of earlier labor materialized in them. When producing a new product the living labor and the materialized labor embbdied in the instruments of labor are acting together.

A special property of the instruments of labor is the fact that they will transfer the labor embodied in them gradually in a given time to the products. Economically the instruments of labor and so the construction machines differ from each other in two main things: in the amount of materialized labor (their value) and in the speed they transfer it to the products.

The value and the process of value transfer in the economical sense reflects the passive role of instruments of labor only.

In aspect of the active role not only value and value transfer but the fitness for production and the use value and it's changes of the machines are also determining factors. Therefore in the valuation of machines and in the analysis of the reproduction of their value both categories of the values and their changes and interaction have to be expounded.

It is known that the machines while in use are subject to material and normal wear and tear, the material wear and tear is in connection

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with the decrease of use value of machines whereas mormal wear and tear or technical absolation is connected with their value and necessitates their reproduction. In simple reproduction both use value and value have to be reproduced.

But the two kinds of reproduction costs are significantly different concerning their basis and for further classification their separate discussion is needed.

3.21 The Reproduction Cost of Use Value:Maintenance Cost.

The use value of machines is foremost a technical economical qualitative category. Use value is the expression indicating that the machine is fit to perform certain jobs.

Another fact to be taken into consideration is that use value is not a constant property in time and while machines are being used it will go through a gradual or an alternative change. The cause of this change is the material wear and tear of the machines.

But the wear and tear of machines is not an irreversable process. Theoretically and also practically wear and tear can always be repaired, parts can be replaced and this way the original properties of the machine, it's use value, can be restored.

When a machine part is worn out the process of transferring its value to the product is completed. In the maintenance (renewal) only this specific value has to be reproduced. By the process of the production of this value however, it is not the original value of the machine, but it's use value is being reproduced. Consequently machine maintenance can be regarded as the continuous process of use value reproduction of the whole machine through the replacement of parts worn out.

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Naturally, the reproduction of use value creates maintenance cost. Since the wear and tear of machines is a function of working time, the maintenance costs are also function of same. The proper technical view of the wear and tear process exposes a continuous periodically repeated chain of the maintenance jobs of different magnitudes which comes with the almost constant appearance of the maintenance cost related to the working time.

Unfortunately again this simple and clear understanding of maintenance process is somewhat in contradiction with the present practice - namely, because the present bookkeeping arbitrarily takes the overhaul away from the row of maintenance jobs and handles it not as cost related to working time but as "renewal part" of the annual depreciation. It is evident that this practice is unjustifiable and also harmful. Unjustifiable because one and the greatest time dependent part of the maintenance costs does not depend only on the initial value and a fixed % of it, called the renewal fraction. Harmful because for instance in a case of increased use of the machinery the reproduction of use value would not be covered.

If for simplicity working time is taken for the basis of relation which is a statistically well definable and plannable quantity, than in a comparative interval the maintenance cost portion that falls to the unit of commodities produced by the machine can be expressed in function of the output of the machine and its utilization.

$$K_u = \frac{u}{i \cdot q_o} \quad \text{Forint/product unit}$$

Where

u = maintenance cost per working hour

i = intensive utilization index

q_o = output norm of machine per unit time.

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3.22 The Reproduction Cost of the Value of Machine Depreciation.

The value of construction machinery is expressed by the necessary labor needed for their reproduction. In the process of production this value is undergoing a two-fold change.

One of them comes from the fact that the acquisition price of a machine under socialist circumstances is not equal to the reproduction cost of same in later years.

Since the productivity of manufacturing industry is increasing permanently the production cost and value are lessening. This lessening of value can be the measure for moral i.e., technical absole~~tion~~cens. There is another way in which machinery loses it's value. This comes from the fact that machinery gradually transfers it's value to the products.

In simple reproduction the value once already produced cannot be lost but it is always reproduced and in the process of value transfer, the transferred value is being accumulated through depreciation. In simple reproduction it is not the original machine value that has to be recovered but only the necessary labor needed for manufacturing it after "t" time elapsed.

Depreciation always appears as a distribution of machine value in "t" time, usually in the form of annual rate of depreciation.

"t" - the time i.e. the lifetime of the machine naturally is a very important factor of this annual depreciation. The amount of annual depreciation related to the working hours or to the annual magnitude of commodities represents a considerable part of the cost. The shorter the lifetime is the higher is the rate of reproduction cost per unit product.

Since machine's lifetime is such an important influencing factor, it has to be calculated by proper methods.

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From the standpoint of reproduction of use value the economic limit of keeping the machine in operating condition is given there where the acquisition cost of an identical new machine will not be less than those of the general repair cost of the old machine (disregarding from operating costs).

Considering that the old machine would be replaced by a similar but cheaper one and the time limit when this replacement is economical to be made, then the equation for the old machine's lifetime can be written up as follows:

$$A\,(1-p)^t - S\cdot A = j\cdot A$$

Where

- A = acquisition cost of the machine
- p = the annual rate of cost decrease in the manufacturing industry
- s = salvage value rate of old machine
- $S\cdot A$ = salvage value which can be taken constant in time
- j = the fraction of general repair costs and the original acquisition cost.

Hence

$$t = \frac{\log\,(j + s)}{\log\,(1 - p)}$$

Figure No. 1 explains the relation.

From the viewpoint of reproduction of the machine value the transfer of value is economical to be *carried on* i.e. it should be completed by the time when the average cost of production in a process by other available means becomes *sufficiently less* than that of by using the given machine for the same purpose any further.

The machine cost is in function with the lifetime as follows:

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$K = G + A/t$

Where

G = sum of the yearly set up, operating and maintenance costs

A = acquisition cost

t = lifetime of machine (years)

K = annual machine cost

But the average industrial cost of the yearly product is continuously decreasing in time.

$K_o = K_o/1-p'/^t$

Where

K_o = average cost at $t = o$

p' = ~~production of~~ yearly cost decrease of related construction industry.

A machine with yearly operating cost (K) should be run in a given production process until the difference in operating cost and the average cost of the given process does not exceed the product of the norm of the index of relative investment effeciency "Δ" and the acquisition cost of a new machine. In this case clearly

$G + A/t - K_o\,(1-p')^t = \Delta\,[A\,(1-p)^t]$

which exponential equation can be solved for t.

In the practice of our days the lifetime of machines is prescribed by orders without further investigations. By this order, the prescribed lifetime of construction machines is 20 years and the annual depreciation accordingly is $\Sigma A/20$. This covers the simple reproduction of machinery and this is the foundation for the reproduction costs of machine value.

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It is easy to understand that the application of same lifetime for all types of machines cannot be correct and the cost elements showed on this basis cannot coincide with the real costs of reproduction. Same deficiency furthermore prevents us from getting a true picture of actual magnitude of machinery cost and the factors influencing it. In considering ~~repairs of~~ these, arrangements for finding the method of establishing economically justifiable norms of machine lifetime should be made.

The two parts of reproduction costs, the one connected with value and the other one connected with use value can be separated only by methods of theoretical investigations. The records of bookkeeping makes this discretion impossible. In the practice the depreciation and maintenance costs are realized in their sum only, and in the cost analysis of mechanization they are usually mentioned as machine rental cost.

These cost elements in the rental cost are represented as annual or monthly fixed amounts. The reproduction cost during the operation of machines is taken into consideration as rental cost. Consequently the rental cost should be the right amount to cover the reproduction cost of the machinery.

For the investigation of these circumstances, the elements, composition and factors of the rent should be detailed.

The rate of rent is determined for the whole set of machines by an almost identical number and it is given per month as % of the value and consequently the rent is represented as monthly cost at the constructions. But the reproduction of machinery is paid by the investors through the unit prices of the building. The part reimbursed in these unit prices naturally is proportional to

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production volume and it cannot be related to the working time of machines as it burdens the contracting firm and especially not to the size of the machinery as it burdens the construction industry.

Presuming that we want to continue covering the reproduction of construction machinery with monthly rents, then the rate of rent has to be a function of the % of rented machines (d%) and of the extensive utilization of machines rented (e%). The equation describing this simultaneous relation shows the monthly % of the rate of rent which contains the reproduction utilization covering all aspects of the use of machines.

$$r = \frac{E + R}{d} + \left(\frac{F + J}{d}\right) \cdot e$$

Where

E = depreciation % per year

R = ~~Rent~~ Overhead % per year

F = renewal % per year

J = repair % per year

The function can be described by a function with two variables and on the diagram (Figure 2) the correct values of the rent are calculated considering the present situation as a case when

d = 100%

e = 100%

It becomes clear that the magnitude of rent necessary for reproduction is certain function of factors, which the fixed cost reimbursed by investors cannot contain. The equation shows that whether we procure the continuous load of the machinery where the rent may be kept on the same level or the rental rate has to be varied according to the occupancy of construction industry.

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If keeping to it, in case of an unfavorable change in the use of machinery either the cost paid by the investors will not cover the rent, the contracting firm pays (the contracting firm pays the difference) or the rent will not cover the reproduction cost (rental firm pays the difference) but anyway it is the construction industry that loses.

In the practice there is a system developed that rent is paid by the month and with it, by the shifts worked considering the number of shifts worked a day. In the most common one shift production, the specific rent cost can be expressed as follows:

$$K_b = \frac{B_{\measuredangle}}{g \cdot q_o} = \frac{b}{g} \quad \text{Forint/unit}$$

Where

$$B_{\measuredangle} = \text{rent/shift}$$

$$b = \frac{B_{\measuredangle}}{q_o}$$

3.3 The Wage Cost of Mechanization.

The operators of construction machines are paid according to the output of machine when it is running and they get hourly wage for all the time when the machine is out of use. Since the extensive utilization of machines is very low, the wage cost of machines belongs rather to the latter category and it can be regarded as fixed cost per shift. Hence the unit wage cost (m) of the product can be expressed approximately as:

$$m = \frac{m_o}{g q_o} = \frac{m'}{g} \quad \text{Forint/unit}$$

Where m_o is the wage of an operator per hour.

3.4 The Cost of Energy Consumption.

This cost element is a very small percentage of the machine

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cost and it mostly proportional with the load of the machine, that is, with the output. This fact permit to consider the energy or fuel cost per unit of product as constant:

L = constant Forint/unit

4.0 The Cost Functions of Construction Mechanization.

It refers to all the cost elements discussed above, that their magnitudes are stipulated data that comes from orders and norms, (As performance norm, rent, wages, energy norm) and on the other hand they are factors in function of construction organization as machine utilization and plant size. The total specific machine cost is derived from the sum of these partly varying, partly constant factors. The elements of machine cost can be written up in following form - according to the order of their discussion in chapters 3.1, 3.2, 3.3, 3.4.

1. Specific set up cost:

   $\frac{F}{Q}$ Forint/unit

2. Specific Reproduction Cost (rent and repair)

   $\frac{b}{g}$ Forint/unit

   Where b = rent burdening one shift (8 hours) per production norm.

3. Specific operating and serving cost

   $\frac{m'}{g}$ Forint/unit

   Where m' = wages cost per shift (8 hours) per production norm.

4. Specific fuel or energy cost

   L = Forint/unit

b and m' are constant for given machines and given circumstances

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and having the same denominator they can be reached using $(b + m') = c$. Thus the total unit cost of mechanization takes the form:

$$K = \frac{F}{Q} + \frac{c}{g} + L$$

which is a simplified form of the cost function. In the equation on the right side, the nominators of the first two members and the third member are constants while the amounts in the denominator of the first two members are functions of technical and organizational orders and parameters.

The mathematical anology of this cost function is an equation with two variables, describing a surface. (Figure 3).

This cost function is an equation that enables us to calculate the changes in machine costs covered by any element and to figure which parameter has what effect on the total machine cost. According to the theorem of finite increments, a small change of machine cost can be expressed as

$$\Delta K = \frac{\partial K}{\partial Q} \cdot \Delta Q + \frac{\partial K}{\partial g} \cdot \Delta g$$

and thereafter the proper substitutions:

$$\Delta K = -\frac{F}{Q^2} \cdot \Delta Q - \frac{C}{g^2} \cdot \Delta g$$

The partial differential quotients of cost function ~~in~~ the so called marginal cost—~~has~~ an important role in the cost analysis. It reacts to the changes in all the parameters and it shows in which sections have certain parameters the most determining effect on cost.

The differential changes of the parameters can be substituted however, by % changes. The results of this substitution is the cost flexibility which tells how much % of change of machine cost

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Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

CONFIDENTIAL

will follow 1% change of plant size or machine utilization. The value of flexibilities denoted by fQ and fg in the equations below show the calculation method of flexibility in function of Q.

$$fQ = - \frac{F/Q}{K} \quad \%/\%$$

and flexibility in function of g

$$fg = - \frac{C/g}{K} \quad \%/\%$$

Table I shows the magnitude of relative cost variation in the neighborhood of reconstructed utilization indexes and plant sizes. 1% change in plant size and machine utilization respectively as it is clear in given case cause different changes in machine costs.

Beyond a certain plant size or machine utilization the changes in the independent variables cause a gradually less and less change in machine costs. But under the present circumstances in construction industry this sensitiveness of costs in function of the given two parameters is great, which means that a small positive change in organization may result in a rather remarkable decrease of cost.

In connection with this fact there is another problem that has to be solved: how can a certain decrease of cost be reached with the least sacrifices required for changing the given parameters?

It can be shown that a maximum decrease in machine costs in function of "Q" and "g" parameters can be obtained if the proportion of related parameter increases is the same as the proportion of differential quotients (marginal costs) thus:

$$tg\alpha = \frac{CQ_o^2}{Fg_o^2}$$

On Table I, $tg\alpha$ values are given for different machines. In every case it is shown that at present the possibilities for decreasing machine cost are by improvement of machine utilization.

CONFIDENTIAL

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

CONFIDENTIAL

For practical proof and utilization of relations revealed in the cost function, the average unit cost of the 6 most common machines is calculated in Table I as it was reconstructable from statistics of 1953. In calculating the cost, the constants of cost function were taken from norms, tariffs and auxiliary resources that is from cost elements fixed for given machines or their use while the dependent variables were taken from statistics. The data of Table I show very illustratively what size of cost elements have formed the average specific machine cost of the listed machines during the time considered and also that what conclusions are allowed by the relative cost flexibility quotient and the parameter function of maximum cost decrease regarding the given parameters. These conclusions point out the fact convincingly that the cost analysis applied is very useful and they also prescribe the principles to be followed in mechanization policy.

5.0 The Economical Limits of Mechanization.

Since by introducing the cost function the mechanization costs are easily plannable and controllable at any level the question arises: what will be the related limits of machine utilization and plant size at a level demanded for. There are two actual forms in which this question appears.

The first one is the more simple and general. Known or prescribed is the maximum specific machine cost of the mechanized technological process using a given machine. With the knowledge of the structure of cost function the solution of the problem is actually finding the corresponding par of Q and g by which the specific cost "K" is less or equal to a prescribed "K" cost.

This problem effects the operative application of machine

CONFIDENTIAL
Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

cost calculation so far that a prescribed cost limit the minimum machine utilization to be prescribed is a function of machine type and plant size.

Different and more complex is the problem when for fulfilling a task a consideration of alternatives is the goal. In this case the question is finding the limit below and above respectively when different alternations are the most economical. The known form of cost function provides a straight-forward way to solve any of these problems.

Applying the above mentioned considerations a method is provided for planning the magnitude of mechanization cost moreover the operative planning can be carried out by keeping to certain limits the parameters. There stands the question though what consideration should be used for calculating the maximum specific machine costs for a given machine? Up to now there was no upper limit drawn or even calculated for machine costs and this lack also hindered the decrease of cost since any single machine cost could appear without control or comparison.

Supposing that there is an upper limit to machine costs that would not be worthwhile crossing and a knowledge of it for orders and setting up norms is inevitable. For the examination of this problem further analysis of cost and especially of machine cost is necessary.

Generally mechanization should result in a decrease of living and materialized labor input comparing mechanized production to (manual) previous techniques. Mechanization can fulfill this task when applied properly by saving more living labor the amount of materialized labor used up in the product during the process of

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

CONFIDENTIAL

value transfer. This means that the total of living and materialized labor per product unit has to show a decreasing tendency. Which fact is the guarantee for the increase of gross productivity.

It is important to be noted, that the productiveness of a firm is essentially different from the one discussed above because it later will show an increase only by the decrease of living labor. This effect in many cases caused a wrong view at the principles of yesterday. Since mechanization as a rule always decreases the labor demand of production but it does not mean necessarily an increase in gross productivity especially not when machine utilization is low.

The relation can more easily be seen through if we talk about the costs of living and materialized labor and demand that the cost of living labor should decrease to a greater extent than the cost of materialized labor increases as a result of mechanization. Which approximately means that mechanization will increase productivity on the national level if and only if it has a decreasing effect on cost. In any other case mechanization will only decrease living labor cost while the total labor needed in the country at least in a given section will increase.

What we really want from mechanization is a decrease of cost comparing to the techniques applied previously. If we establish what we mean on previous techniques and accepting it, we calculate that the cost level that existed up to now, then we require order from the mechanization that the machine cost should not exceed the cost calculated this way. In the case of particular construction industry, it seems to be the most advantageous way to take manual work as a basis for the comparison.

CONFIDENTIAL

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

CONFIDENTIAL

This way we have chosen a method that in applying any machine the maximum of its specific cost, is expressed by the cost of an equivalent manual work.

Assuming the role of mechanization in socialism generally it cannot be said that in every case when mechanization does not need a decrease of cost comparing to the cost of manual labor, mechanization should be omitted. The present organization of construction industry and the demand for labor power typical in socialism, obliges us to apply machinery at a great extent. Naturally this has an economical limit too. As on company level the mechanization of higher cost always causes loss so on national level may appear the case when mechanization is not economical even though it means a saving in gross labor power. The calculation of this maximum cost limit is as follows:

The starting point of this consideration is that the application of machines relieves labor power, which then can be used in another field of national economy for production of value and by that increases the total production while on the field mechanized related wage costs will be saved. In this understanding the machine costs can even exceed the wage cost of manual work up the point where they reach the new product value of equivalent manual labor because this is the limit up to which the mechanization is economical for the national economy by saving labor power.

For the purpose of these calculations the relation to be established were between wages, cost of manual labor and the new labor product value of the manual labor has to be laid down.

1. In the construction industry besides net wages there is 29% so called social burden which includes taxes proportional to wages - board and social services; and 59% so called census-

CONFIDENTIAL

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

proportional extra cost, which consists of allowance or travelling cost, cleaning, in many eases education, protective outfit, winter complement, etc. These cost elements represent a total of 88% of the wages, from this the factor is 1.88.

2. The production employees have to produce the production value for the inproductive employees - so their wages too. Presuming that the wages of inproductive employees is 25% of the total - as an industrial average - the factor related to basic wages is 1.25.

The productive employee has to produce the difference between consumption basis and national product, i.e. according to the 70% of consumption basis repscribed by the government program of 1954, 1/07 of it - which means a factor of 1.43. Since the application of machines always relieves productive employees - multiplying the mentioned 3 factors it comes to the conclusion that 1.88 x 1.25 x 1.43 = Forint 3.35 labor product value falls to 1 Forint net wages cost of a productive employee in construction industry. This number which is a very interesting data of the national economy from the point of mechanization expresses that the saving of manual labor time provides Forint 2.35 national production plus product beyond every one Forint actual wages saved.

It is known that application of machines while increasing the productivity on the other hand may also increase the cost. This increase of cost is permitted only if balancing this there is a suitable amount of labor power relieved. This means that the application of machines may cause an extra money cost, - the so called substitution cost in some cases in practice but this substitution cost certainly cannot be of just any magnitude. The limit for substitution cost is at the level where the costs of mechanization

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Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

CONFIDENTIAL

consume but do not exceed the product value of substituted manual labor.

The maximum of substitution cost is 2.35 . 290 = 6.80 presuming that the average wages in construction industry is 2.90 Forint which means that the extra cost of mechanization permittable is 6.80 per substituted one working hour. Up to this limit we can still talk of economy of construction industry in national terms. Cost above this limit means loss on the level of company and national economy as well.

The notice of substitution cost (opportunity cost) in the national economy has for long been wanted for development of the economy of mechanization.

The fact that figures of machine cost were hard to obtain and a certain under evaluation of the program of cost decrease led to mechanizations applied immoderately with the motivation that the goal of mechanization in construction industry is first of all decreasing the demand of labor and that such effect of machines can only be profitable for the national economy. The introduction of substitution cost points out that the erroneous understanding of machine application does not necessarily agree with the interest of national economy and that the economy of mechanization has to be calculated or at least it's upper limit had to be drawn in the future.

Table I contains besides the reconstructed Q values, those minimums of g which indicate the economical limits for the firm and for the national economy.

6.0 Relations Between Mechanization and Productivity.

Mechanization, by changing the composition of productive forces

CONFIDENTIAL

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

CONFIDENTIAL

and with that the proportions of the two most important production factors - labor power and instruments of production as it was pointed out earlier, has a double effect: increases productivity and decreases cost. These two effects do not answer the changes in the measure of mechanization with the same susceptibility and definiteness.

Expressing the total input in the form of living labor (Me) and materialized labor (Mn) it can be proved that the productivity of living labor (t) in the form of

$$t = \frac{T}{Me}$$

increases more rapidly with the decrease of Me than the productivity of the total labor "t_0".

$$t_0 = \frac{T}{Me + Mn}$$

which is reciprocal to total costs.

Consequently when a decrease of Me is obtained by mechanization, it's effect will necessarily appear at a greater degree in the increase of productivity than in the decrease of cost.

This fact makes it possible, moreover, necessary that we involve the analysis of productivity of mechanization into the technical economical analysis of mechanization. There are two main fields to be studied:

1. At what extent, in what function and how will the productivity of laborers that is the productivity of working process develop with the application of machines?

2. How is the productivity index of the whole firm or industry related to mechanization?

It is known that the machine operator is supplied with machine as instrument of production and his productivity is a function of the

CONFIDENTIAL

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

CONFIDENTIAL

equipment. It is an adjacent idea that the development of productivity in the comparison and valuation of different machines should be expressed in function of machines available to use. For this purpose an index of machine supply has to be derived. This index is called degree of mechanization, denoted by $\mathcal{E}$ and it's dimension is

$$\mathcal{E} = \frac{\text{machine value}}{\text{number of laborers using it}} = \frac{G}{L} = \text{Forint/men}$$

The degree of mechanization lies on a very deep economical basis. It's magnitude at a given and constant composition of instruments of labor is proportional with c/v index of Marx's reproduction scheme.

In the analysis of productivity of laborers working with certain machines in the function of degree of mechanization, important fundamental laws are found. The form of $t = f(\mathcal{E})$ function shows that the change of degree of mechanization the machine value per person - effects the productivity of laborers. That is why $t = f(\mathcal{E})$ function has it's important economical interpretation.

Figure No. 4 for instance shows that $t = f(\mathcal{E})$ function of different concrete mixers used in construction industry. On the abscissa are the machine values the machine operator disposes of and the ordinata indicate the 100% production per working hour. This empirical relation shows that by increasing the machine size per operator, the productivity increases first slowly then faster then slower again.

The increase of degree of mechanization naturally is the most effective and profitable where the increased productivity per machine value per person is the greatest that is where

$$\frac{\Delta t}{\Delta \mathcal{E}} = \text{maximum.}$$

CONFIDENTIAL

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

CONFIDENTIAL

$dt/d\mathcal{E}$ function, i.e., its values have to be interpreted distinctly. It has the same marginal productivity. As long as the marginal productivity is growing, the machine values added to increase of the degree of mechanization, effect the productivity positively. From the point of productivity the criterion of most economical mechanization is at the maximum of $dt/d\mathcal{E}$ curve. Beyond this point the added machine values will still increase the productivity at a declining degree. For example in the case of concrete mixers chosen, the degree of mechanization was increased by taking machines of higher and higher capacity. Figure 4 shows that from the point of productivity Gr 18,000 Forint value, 4.5/m³ capacity (250 - 275 L) mixer meets the optimum.

It is interesting that the practice applying intuitively the law of marginal productivity considered this machine type as the most useful and it is the most common.

The application of machines effects the productivity of the whole production process by changing the average composition of production. This effect is very important because it appears within the range of data registered statistically, that is, it is based on unanimously plannable and controllable relations. In spite of this up to now there was no scientifically based statistical method known in the literature or in the practice that would have revealed the objective relations between the quality and quantity of mechanization and productivity.

Our analysis is introduced by the following establishments. The techniques of construction industry at its present stage is a rather mixed manual-mechanical productive process. The operations within this process are vertically articulated and a peculiar property of this verticality is that the technological process is

CONFIDENTIAL

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

CONFIDENTIAL

serial with hauling and transportation operations. In the mechanization of construction industry the heavier and labor demanding operations, mostly auxiliary labor, are mechanized first. Most of our construction industry machinery is made for substitution of auxiliary works. Consequently in the production process of substantially unchanged technology the mechanized operations being vertically connected with manual labor, the speed of production is still determined by latter.

Under such circumstances the manual works can be divided into two groups from the point of mechanization, a) labor that can be substituted by machines (mostly auxiliary workers), b) labor unsubstitutable by machines. The productivity of production process will be increased according to the extent of substitution of labor by machines.

The substitutable labor however, can be substituted only to a certain extent dictated by the given techniques, that is until the proportion of substitutable and unsubstitutable labor characteristic to given techniques is reached.

In order to make it possible to increase productivity permanently and without limit, it is essential to change the technique of construction that limits the productivity increasing effect of mechanization through the constant proportion of substitutable and unsubstitutable labors. The task then is to improve techniques, apply modern organization ideas, prefabrication and modern machinery.

The next step is to analyse the mathematical interpretation of this relation. If Mc = number of laborers working in the mechanized productive process that cannot be substituted on given stage and Ms = the number of substitutable laborers

T = the final product (use value) of given time interval.

CONFIDENTIAL

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

CONFIDENTIAL

then the productivity "t"

$$t = \frac{T}{Mc + Ms} \quad \text{Forint/person}$$

Suppose the quantity of substitutable labor partly or in total will be substituted by machinery. For this supposition we also need to know, that how many persons labor can be substituted by a machine and for that the category of working power equivalent is introduced. Working power equivalent is an index showing on the basis of a comparison, that how many laborers could have done the same job working the same hours that the machine has completed in certain time. With the introduction of working power equivalent a unanimous relation is found between the machines and labor quantity or number of laborers substituted.

The relation between working power equivalent of the machines and value of same individually and generally, leads to an important conclusion. For the expression of this relation a new parameter of the machines has to be introduced - the so-called specific working power equivalent "n", which is the quotient of working power equivalent and machine value, referring either to a single machine or to a group of machines,

$$n = \frac{N}{G} \quad \text{person/1000 Forint}$$

and it tells how many laborers can be substituted by 1000 Forint worth of machines.

Twenty construction machines were involved in the analysis of this relation.

A table has been completed (Table II) for the analysis of the relation and the equation of the curve, characteristic to the relation also has been established which can be simplified to a simple proportionality with a little negligence and in our further

CONFIDENTIAL

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

CONFIDENTIAL

discussion G = 2.1.N that is $n = \frac{N}{G} = 0.48$ equation can be used. The relation means that in construction mechanization 2100 Forint machine value will relieve 1 laborer (presuming 100% utilization).

This very useful final result provides a basis for the description of the effect of mechanization on productivity by means of simple considerations and relations. It has to be noted that the relation above cannot be generalized and the results derived refer to the 20 machine types - that were involved in the analysis. For instance a very different number is characteristic to heavy loading machines and excavators but this difference does not influence the correctness of our thought because at a given calculation actual data of related machines are being taken.

The expressions of productivity - caused by substituting partly or in whole Ms number of laborers is

$$t = \frac{T}{Mc + (Ms - nG)}$$

But it is known that machine value in itself says little about the degree of mechanization and for this it cannot be used without considering the number of laborers employed with it's operation. An earlier accepted parameter for the degree of machine supply is the degree of mechanization which is also an index of composition of productive forces.

The degree of mechanization in this case is a quotient of machine value and the number of laborers operating it can be written as follows:

$$\mathcal{E} = \frac{G}{Mc + (Ms - nG)} \quad \text{1000 Forint/person}$$

and drawing this equation and the previous together =

CONFIDENTIAL
Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

$$t = \frac{T}{G} \cdot \mathcal{E} \qquad \text{product/person.}$$

That is how we arrived to the relation between mechanization and productivity.

The change of productivity is proportional to the change of degree of mechanization. The slope of the curve is a function of T/G multiplier - the amount of products actually produced.

In the following paragraphs the main conditions of our conclusions are discussed and the moditication of the relations after the release of the abstractions are analysed.

1. Supposing that the increase of mechanization is accompanied by a total compliance of the productive forces. That is the substitutable number of laborers determined by the stage of techniques is being relieved by machines whose productivity quantitatively and qualitatively as well is fit to the productivity of substituted number, so that the machine work will complete the work of the unsubstituted laborers just as the previous number of substituted laborers. When applying this principle we find that there is an optimal proportion of machines and operators for every type of machine which provides the most efficient condition of the productivity increase. There is an optimum of degree of mechanization providing this proportion - supposing 100% utilization. Optimum because an increase of mechanization above the degree determined by compliance with the given techniques usually will not increase the productivity but lessen the utilization index of machinery only.

2. Our conclusions up to now were made presuming a 100% utilization. It is well known that this condition in practice can very rarely be provided. The question is what is the effect of the fact that the machine values applied do not perform 100% output but only

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

a "g" portion of it which is the utilization index? Naturally the decrease of utilization will cause a proportional decrease of productivity or what is the same, the actual working power equivalent, i.e., the number of substituted laborers. If "G" machine value substitutes "nG" number, at 100% utilization, then at a "g" % utilization it will relieve only g.n.G laborers. From the point of productivity it can be interpreted as if a machine value multiplied by "g" would only be applied in the production. This value differing from nominal machine value is called active machine value.

3. The methods of increase of mechanization also have to be analyzed. Two extreme cases of it are the following:

In the first case - the increase is done by applying universal machines of greater and greater value. In this case emphasizing that the condition of productive power compliance is provided by the specific working power equivalent will determine the form of $t = f(\mathcal{E})$ curve. And the specific working power equivalent at least at the beginning increases with the growth of machine and plant size.

In the other case the number of machines is increased. The more machine is applied however the less the condition of compliance can be kept and the lower the average utilization will be and in function of normal degree of mechanization the $t = f(\mathcal{E})$ curve will be declining. (Figure 5).

An important final task is to contour some of the principles that come from the revealed relations. First of all it has to be pointed out that as the average utilization index of construction machines show the productive forces most efficient compliance from the point of productivity is not provided. A general symptom is the

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

CONFIDENTIAL

lack of harmony between substitutable and unsubstitutable operations. Speaking in technical terms the capacity of manual operations related vertically to mechanized operations does not reach the capacity provided by the machines by far. Under such circumstances, since the unfavorable utilization conditions common in the industry, refers to all the new machines to be applied, the machine values brought into the production at great sacrifices, will be activated only in 1/4 - 1/6 fractions and for this in cases of greater mechanization the degree of active mechanization will remain low and the productivity increase will be very slow. It has to be concluded that the adjacent operations of productions, manual operations are fit to a much lower degree of mechanization insuring total compliance.

The organization and technique of construction industry did not follow the speed of machine acquisition and supply. In order to provide the ground for more active mechanization, it is not the mechanization but the possibility for mechanization that has to be increased. An increase of degree of machines ation cannot be a goal for itself, and it does not necessarily mean the increase of productivity at all.

Under present circumstances the increase of productivity by means of mechanization is almost exclusively a matter of providing the possibilities of mechanization; that is a matter of improving the organization and technical development of the technology of construction industry.

For the sake of above mentioned an organization of construction that stands on the ground of optimum compliance of productive forces has to be applied. When carrying out the operations that were planned on this basis, no allowance should be made because of lack of laborers; that would be against the number providing the

CONFIDENTIAL

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

conditions of compliance. Generally it cannot be permitted that for saving a little living labor - a great deal of materialized labor would be sacrificed. The means of fight against lack of labor power is not forced mechanization, but the decrease of number of simultaneous constructions. That is how the national economy obtains more products because the high degree of mechanization provides the higher productivity of all the laborers and not by having built much at a low rate of productivity.

It is time that the practice of our construction organization will solve the problem of the total compliance of productive forces according to the nominal machine supply possibilities and the results of this work has to be shown in forms of orders that would contain the minimum number of laborers to work with every machine and techniques that will make a high utilization possible.

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

CONFIDENTIAL

TABLE I

No.	Name	Notation	Tower Crane	Brunn Crane	Conveyor	Concr. Mixer	Mortar Mixer	Excavator	Remarks
1	2	3	4	5	6	7	8	9	10
1	Machine Perfm. (to/hr) (m³/hr)	q_o	20,--	5,--	10,--	3,5	2,2	60,-	
2	Work. power equiv. (Person)	N	75,--	10,--	13,--	7,-	3,-	69,-	
3	Exten. utiliz. index %	e_n	70,--	25,60	36,70	23,6	27,6	40,5	
4	" " " %	e_e	40,--	34,--	34,--	34,--	33,-	0,7	
5	" " " %	e	68,--	40,--	43,70	28,--	25,-	73,-	
6	Inten. " " %	i	37,60	53,--	38,--	71,--	76,-	72,-	
7	Integral " " %	g_ϕ	25,60	21,2	16,80	20,-	19,-	52,5	$e_3 \cdot i$
8	Avg.setup cost (1000 Ft./setup)	F	47,20	2,46	0,572	0,524	0,468	11,-	
9	Avg.setup time (hr/setup)	F_e	30,40	90,--	36,--	29,--	27,--	3,-	
10	Avg.plant size (1000 to or m3/site)	Q_o	9,20	0,386	0,331	0,186	0,154	20,40	
11	Spec. setup cost (Ft/to;Ft/m3)	f	5,13	6,36	1,73	2,82	3,04	0,54	$f = F/Q$
12	Avg.fixed mach.cost (Ft/to,m3)	c	2,14	2,61	0,61	1,12	1,80	1,30	
13	Fuel cost (Ft/to,m3)	L	1,09	1,50	0,70	1,40	2,30	0,50	
14	Avg.oper. cost (Ft/to,m3)	c/g_ϕ	8,35	12,30	3,64	5,60	9,46	2,48	12/7
15	Spec.mach.cost (Ft/to,m3)	K	14,84	20,56	6,14	10,02	15,16	3,52	$K = \frac{F}{Q} + \frac{c}{g} + L$ ~~u + 0,2 m~~
16	Rel.cost flex. for Q %/%	f_Q	-0,35	-0,31	-0,28	-0,28	-0,20	-0,15	$f_Q = \frac{F/Q}{K}$

39

CONFIDENTIAL

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

TABLE II CONTINUED

1	2	3	4	5	6	7	8	9	10
17	Rel.cost flex.for g %/%	f_g	-0,57	-0,60	-0,59	-0,55	-0,62	-0,70	$f_g = \frac{c/g}{K}$
18	" " " in % of g	f'_g	-2,22	-2,84	-3,50	-2,75	-3,30	-1,33	19./20,./
19	Marginal cost of Q	$-F/Q^2$	-0,56	-1,74	-5,2	-15,-	-19,50	-0,03	
20	" " " g	$-c/g^2$	-32,7	-58,-	-20,6	-27,9	-50,-	-4,72	
21	Param.of max.cost decrease	$t_{g\alpha}$	57,-	33,-	4,-	1,86	2,64	17,--	20./19./
22	Work.time/prod.unit with machine (hr/m3)	m_e	0,10	0,20	0,05	0,214	0,272	0,1	operators 1.po
23	Work.time/prod.unit in manual process (hr/m3/	m'_g	3,75	2,--	1,30	2,--	1,36	1,15	1/N
24	Cost of man.labor (Ft/m3, to)	K_e	10,90	5,80	3,77	5,80	3,95	3,62	2,90 x 23
25	Subst. cost (Ft/hr)	h	1,05	8,20	1,92	2,37	10,28	-	$\frac{K-K_e}{m'_e-m}$
26	Econ.margin for firm (%)	g_m	50,-	?	48,-	81,-	?	50,-	
27	" " " nat. economy (%)	g_m	10,50	43,50	10,50	18,80	60,--	20,--	

CONFIDENTIAL

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

CONFIDENTIAL

REMARKS TO TABLE I:

1. The machine cost of all (except excavators) was higher than the cost that the normal laborer needed for completing same job would have been - referring to the utilization and operating conditions of 1953. But this comparison does not take the speed of work into consideration.

2. The "c" value at the cranes is remarkably increased by the fact that the norm of operations is well below that of the machine capacity.

3. On the cases of Brunn crane and the mortal mixer the cost is 1.4 - 2.6 times as much as the cost of manual work of the same output. The cost function constants are so high that even a 100% utilization would mean less for the firm.

4. The application of Brunn crane and mortar mixer is complete loss not only on firm but on national economy level as well. The substitution cost of 1 hour is above 6.80 in both cranes.

5. The proportional increase of machine utilization decreases the machine cost 2-4 times as much as the increase of plant size. For instance 1% increase in utilization meant 2.75% decrease of machine cost, in case of concrete mixers ~~were~~ between 20-21% utilization.

6. In the cases of tower crane, Brunn crane, excavators and conveyor, it is enough to improve the utilization while in cases of mixers, the plant size has to be increased for quick decrease of machine cost. (See 4a)

7. The data of rows 26 and 27 are correct only at the average plant sizes of 1953.

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Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

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TABLE II

CONNECTIONS BETWEEN THE VALUE AND WORKING POWER EQUIVALENT OF MACHINES IN CONSTRUCTION INDUSTRY

No.	Name of Machine	Machine Value G (1000 Forint)	Working Power Equiv. N. (Person)	Specific Working Power Equivalent (n)
1	Conveyor 6-10 m	12	6	0.5
2	Conveyor 15-20 m	50	28	0.56
3	Cement pump	15	8	0.53
4	Vibe~~rator~~o sieve	24	11	0.46
5	Concrete viberator	10	3	0.30
6	Elevator	55	27	0.49
7	Concrete mixer 150 L	17	8	0.47
8	" " 275 L	22	14	0.63
9	" " 375 L	36	17	0.47
10	" " 500 L	31	21	0.68
11	Mortar mixer 150 L	17	4	0.24
12	" " 200 L	35	6	0.17
13	" " 325 L	26	9	0.35
14	Mortar pump $3m^3$/hr.	23	9	0.39
15	" " $6m^3$/hr.	28	18	0.62
16	Brunn crane	49	28	0.57
17	Deck crane	19	10	0.52
18	Clam shovel	25	18	0.72
19	Portal crane	54	15	0.28
20	Tower crane	300	140	0.47
				$\bar{n} = 0.48$

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Fig. 1.

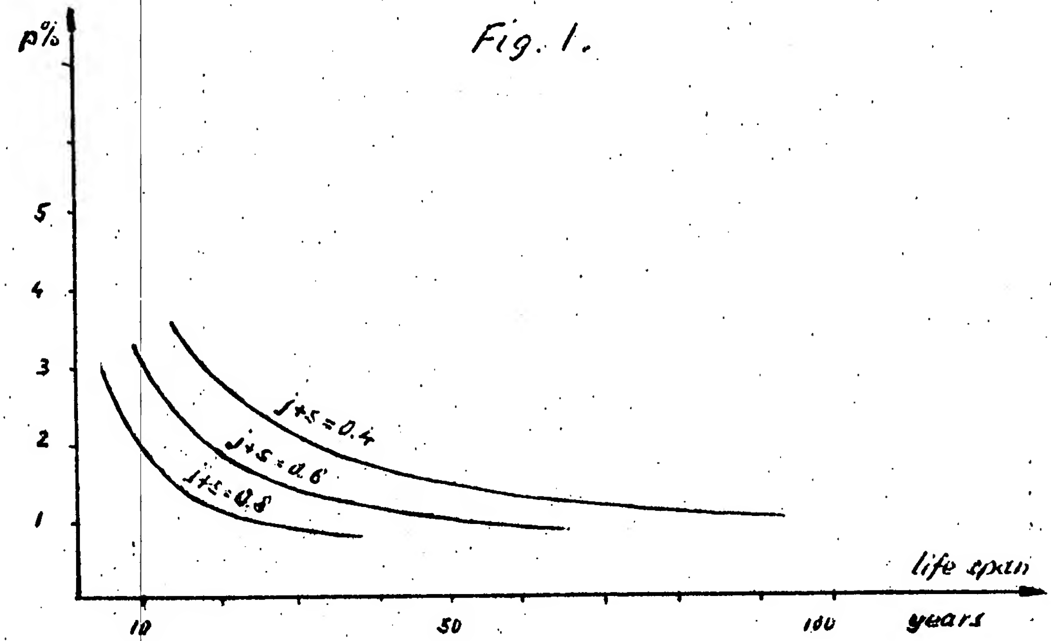

Fig. 2.

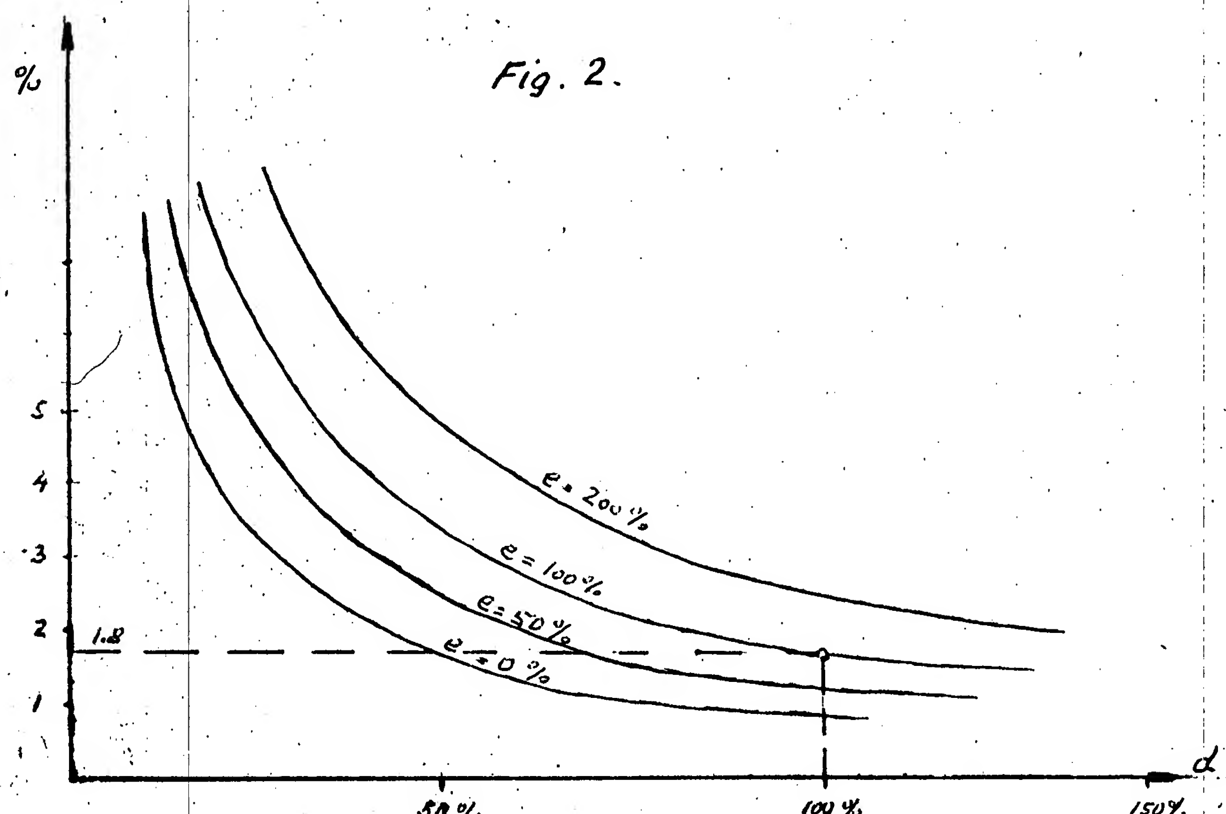

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Fig. 3.

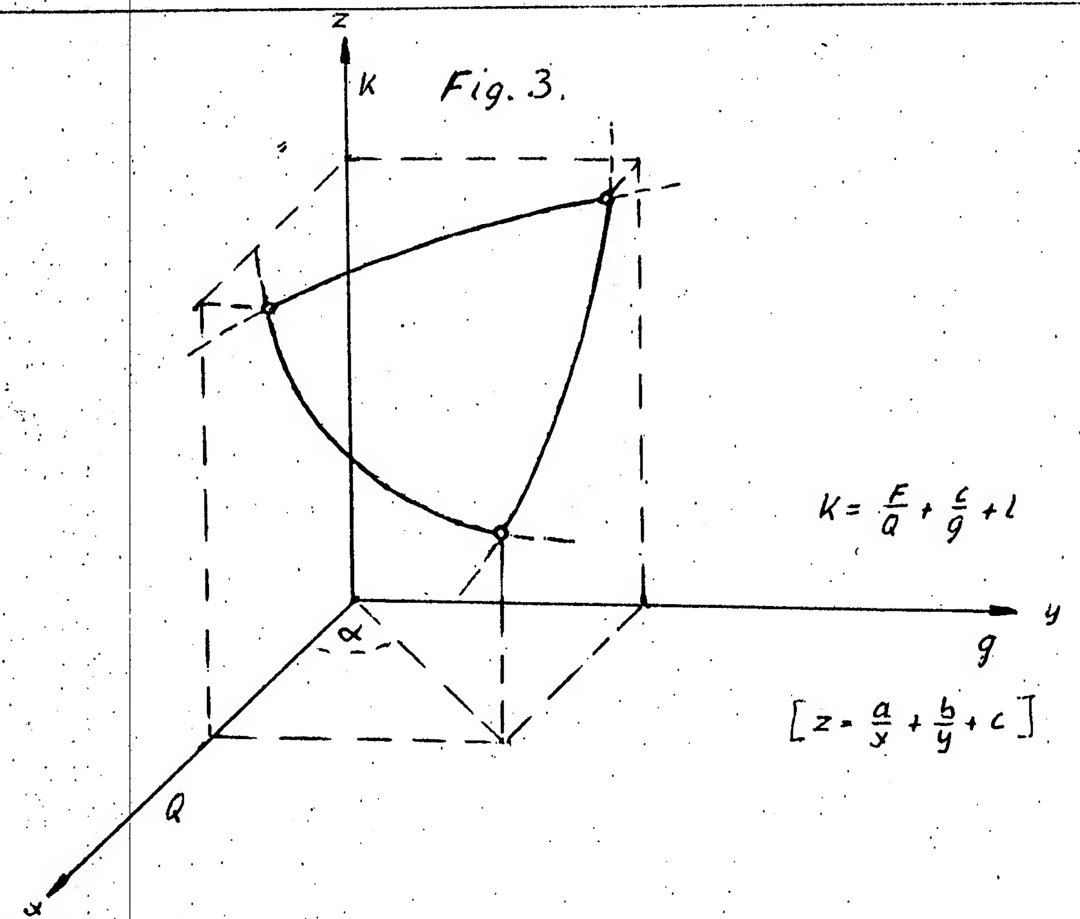

Fig. 4.

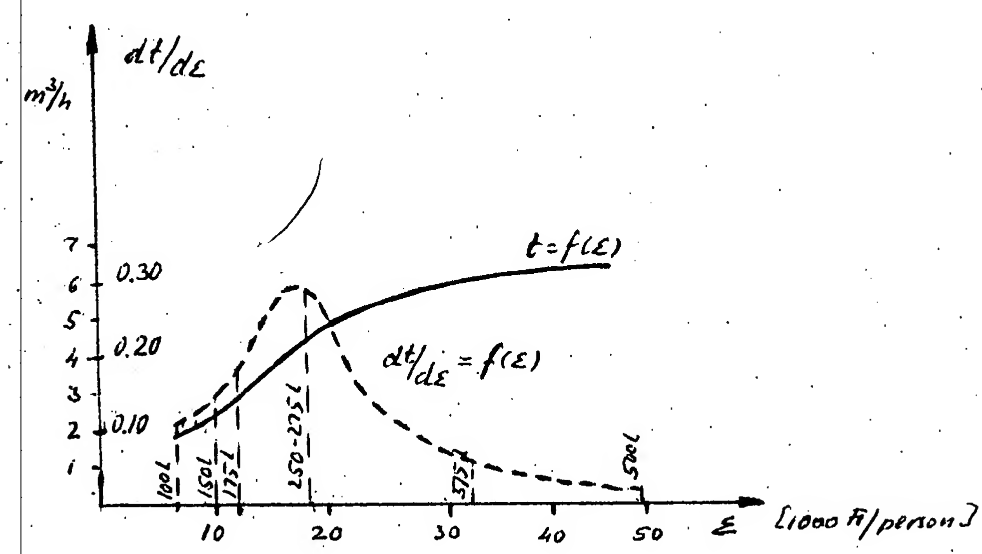

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Fig. 5.

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Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

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1. THE GOALS OF MECHANIZATION

There were many goals of mechanization known in the construction industry mostly as slogans. This situation came from the fact that goals and accomplishments were never compared objectively.

The most frequently emphasized goal of mechanization was that mechanization relieves workers from heavy manual work. This idea posed the communist government which acquired the machines as benefactors of workers, that led to abuse of equipments and money whenever the mechanization did not serve also more realistic purposes. A general mistake which arose from this aspect was that workers and engineers were inclined to think in terms of certain single labor consuming operations trying to replace them by a particular machine instead of trying to replace the whole technological process by a more advanced and mechanized one.

The political economical goal of mechanization was the increase of productivity. It was generally understood that higher productivity is better than lower, no matter by what means it was accomplished, and consequently, became one of the most important indicators of the successfulness of firms and industry. This was however, a very misleading figure. Disregarding from the common misbelief that every gain in productivity has to be attributed to some sort of mechanization which was naturally not true, the category of product-value was a completely insufficient measure. The Forint-value of construction expressed not only the quantity but also the quality of products, making every comparison incoherent. In addition it reflected also every increase in wages and material cost which clearly had nothing to do with productivity. The problem of lack of a unique measure for product value in construction, hence the correct measure of

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productivity is one of the most serious shortcomings in the economics of the industry up to present days. The only way of calculating productivity terms is that one used in the dissertation, when product-value is expressable by quantities as m^3 or ton. These quantities cannot be related, however, to end-products, but only to certain phasis of construction works.

Another general goal set ahead of mechanization was the acceleration of the speed of production. This goal could be achieved naturally only when the mechanization represented itself a well defined technological process, independent from others, like in the case of earth moving and road building machines and prefabrication in general. Whenever mechanized processes were connected in series with traditional manual production - as it was in all other cases - the latter determined the speed of productions and machines became idle. It was frequently told that the expansion of mechanization is needed first of all in order to serve the interest of the expanding prefabrication. Namely the prefabrication was forced by all means. The hoisting power was not only the technological advantage of prefabrication - the products were almost exclusively reinforced concrete elements - but mainly the acute shortage in timber. This fact resulted in credible extremities, for instance the investments and continuous use of cranes capable to hoist prefabricated elements weighing 40 tons up to 50 meters high. The increased element, size, since the consequence of prefabrication became enough justification to invest heavy duty cranes, no matter how their capacity could be exploited in time. Thus not the mechanization itself, but actually the advancement in technology did effect the speed of production.

A practical goal of mechanization known by the contractors

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CONFIDENTIAL

was the general presumption that using machines they can substitute workmen. It was actually an effort identical with the political economical goal of mechanization but had entirely different roots. There was an acute working power shortage in all sections of national economy and contractors never had enough workmen needed to fulfill their compulsory plans on time. They thought intensive mechanization may solve their labor problem and demanded machines in great number. As it is shown in the dissertation (chapter 6.0) this demand was based on a misbelief because the moderate number of substitutable workers at the given, generally traditional construction technology, never could inflate the number of workers in the other connected processes so much that either the speed or the productivity of the whole process could have shown conceivable gain. In contrary the attitude of contractors described above was responsible in first place for the uneconomical over mechanization observable throughout the industry and appearing in the low machine utilization indexes and high cost.

It was never stated that mechanization should or could decrease cost. Cost usually did not play a role in considerations concerning mechanization. As it is mentioned in the chapters 3.1 - 3.6 of the dissertation the actual cost of mechanization was practically not controllable.

2. THE ACTUAL RESULTS OF MECHANIZATION

A. About 40% of earth moving jobs was only done by machines. The main reason was besides the lack of excavators the fact that the size distribution of excavators did not match the size distribution of working sites. There were no small excavators, under 0.5 m^3 capacity and multipurpose loading machines available and therefore, all the smaller and finishing jobs, a large quantity in it's sum, were done by manual work.

CONFIDENTIAL

Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

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B. More than 90% of concrete mixing was mechanized. Moreover a considerable amount of this was produced by central, semi-automatic mixing plants. The reason of investing the latter was the possibility of using selected gravel hence saving some cement, that is coal, in which there was always a short supply. Considerations like this helped to distort in many cases the economic soundness of investments. A matter of fact, never any of the 10 or 20 central mixing plants were used with full capacity. In the lack of loading equipment the transportation and feeding jobs at the numerous (about 800) single concrete mixers were done by manual instruments. Two or three concrete pumps were used in the whole industry for demonstrating purposes. There were experiments with floating cement transportation and containerization.

C. More than 200 mortar mixers were invested and used, usually in connection with mortar pumps of pneumatic or piston type. The mechanization of mortar production in this extent was fairly well solved, better for instance than in Poland or in Czechoslovakia. Only the sand transportation and loading remained technologically unsolved.

D. Hundreds of elevators and cranes, including about 40 tower cranes were used mostly for vertical transportation in the industry. With a very few exceptions, none of them was mobile in the sense as it is used in U.S. but they were either fixed on one single place (elevators, deck cranes) or on rail (Brunn, tower crane). It can be said that the amount of cranes could satisfy the demands for vertical transportation but there was the feeling of the need for more tower cranes although their type (U.S.S.R. patent) was regarded obsolete. The reason: tower cranes could do loading and certain horizontal transportation too, for which no

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machine existed. As it is known, vertical transportation is only a part and rather small part of all the transportation needs around a building and therefore all the constructions without tower crane, that is the majority of them, were evidently very poorly mechanized. Even the tower cranes had the disadvantage of fixed rail and radius, thus many of the loading and transportation duties remained beyond reach. There was a general shortcoming in mobile cranes and multi-purpose loading machines mainly because they were not produced at that time within the soviet block.

E. The mechanization had undoubtedly a considerable indirect effect on the construction industry by expanding the possibilities of prefabrication. Application of large size panels (up to 2 tons) made of concrete or brick, gained place continuously. In industrial buildings complete frame structures were prefabricated, and lifted in their position by special cranes. Using traditional materials like heavy concrete and brick, and in the lack of new building materials, however, the possibilities of mechanization were exhausted at this point. (See dissertation chapter 6.0).

3. THE CONCLUSIONS OF THE 1955 STUDY

The 1955 study was the first thorough scientific investigation of the circumstances of mechanization in construction industry. This fact itself includes a general conclusion: until this time every machine investment activity was done necessarily in a spontaneous, irresponsible way, in the lack of correct data, method of analysis and possibility of predictions.

Other general conclusion of the study was the fact that mechanized processes turned out to be more expensive everywhere than the corresponding manual processes. The mechanization

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did not decrease but in the contrary helped to increase the unit cost of constructions.

Finally it was postulated and later proved that further increase of the degree of mechanization quantitatively and without favorable change of technology, yields sharply diminishing return in productivity.

More detailed major conclusions are as follows:

a. Set up cost of machines, although operatively neglected, represented too high portion of machine cost. This fact can be contributed to two complementary factors. There were no mobile machines, and the size (lot size) of constructions was unfavorably dispersed. Machine investments were mostly made evidently with the incorrect presumption of large-scale jobs only.

b. The system of handling reproduction cost in the construction industry as well as everywhere in communist states was found to be in sharp contradiction with the Marxist interpretation of the value theory (Chapters 3.21, 3.22). In addition the actual methods of writing off did not provide sufficient conditions for simple reproduction.

c. The machine utilization index turned out to be the most important parameter in mechanization. It measures both the effectiveness of organization and the level of cost. The incredible low industrial averages reflect a large gap between the capacity of connected mechanized and manual processes and are responsible mainly for the high machine cost (Chapter 4.0). The basic source of trouble was the general disproportionality between the number of machines and number of workmen applied in consecutive operations, due to the shortage in labor supply and negligence in organization. The

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Approved For Release 2009/04/29 : CIA-RDP80T00246A009500010001-5

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introduction of the concept of flexibility in pointing out the cost-effect of utilization index, and the call for standardized ratios in man-machine systems were the most important propositions emphasized in the dissertation.

d. It was necessary to set up cost levels by limit values of parameters, especially that of the utilization index, above which the use of machine could not be regarded justified economically. It was a significant conclusion that the wage cost of compared manual works was not proposed to be accepted as single limit, but also substitution cost, a term similar to opportunity cost had to be introduced to enlarge the margines of economically sound mechanizations.

e. The introduction of the concept of degree of mechanization and expressing the productivity in function of same - a relation which strangely enough was undiscovered in the whole soviet dominated economic literature until this time - provided the most valuable conclusions, a new look, immediately accepted in practice as well as in methodology in Hungary. It turned the attention generally towards the qualitative factors in technical developments and partly cleared the way of the application of econometric methods in investment planning.

4. OBSERVATIONS OR CONCLUSIONS OMITTED FROM THE 1955 STUDY FOR POLITICAL OR OTHER REASONS

The 1955 study was very critical and no observations were omitted as far as the facts were concerned because the author was personally independent from the industry. Some conclusions, however, derived during the analysis were not mentioned in the study because of political and ideological reasons.

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There was political reason not to attack the Hungarian price policy, which was found to be completely inadequate for the analysis of economic effects as well as for long run planning. Too low wages, artificial raw material prices, too high cost of acquisition and maintenance of machinery made every economic comparison illusoric and created a conflict between the interest of firms and national economy. The firms were only interested in fulfilling the monthly or quarter yearly production plans and reimburse their total cost. No productivity terms and ~~ne~~ level of unit cost was among their incentives. Even the economic thinking and the possibilities of analysis were discouraged by party directives concerning plans, saving of labor, timber, coal, import materials etc. Prices themselves were and could not be regarded as fixed basis for economic considerations and without this no investment policy could be worked out. Actually this was the cause why the author had to introduce the concept of opportunity cost into his economic comparisons.

Ideological restrictions were imposed on the author by the fact that Marxist economics does not know cost and production functions neither marginal cost or productivity, regarding latter as a part of marginal utility theory, a completely unacceptable thing for Marxism. In a study, however, where not only the facts about cost and productivity but also the analysis of mechanism by which favorable change can be accomplished was the subject of investigations, terms like elasticity ~~flexibility~~ and marginal productivity had to be used. Since no reference was advisable to make to capitalist economics, the author developed and used these terms as purely logistic mathematical

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models and thus successfully "smuggled" a complete set of relatively new terminologies into the Marxist literature.

5. NEW OBSERVATIONS OR CONCLUSIONS DEVELOPED SINCE 1955 RELATIVE TO THE 1955 STUDY

The methodology and results of the 1955 study were accepted and appreciated among exedutives of the industry and a research group was formed in the next year to analyse the statistical data of the whole construction industry in the past five years by econometric methods.

First time series were calculated and correlation analysis was made within a large variety of interrelated factors. One of these calculations showed a strong correlation between time series of the total number of brick layers employeed in the industry and the time series of the weighed average machine utilization index. This result verified the theory included in Chapter 6.0 of the dissertation and the statements made under 3.c of this report. A further proof was found and showed the technological limitations upon mechanization by discovering that the machine utilization index was declining while the degree of mechanization was increasing during the five year period. In other words, the increased number of machines was being used in less extent. This fact also included the verification of the diminishing return in productivity as function of mechanization since declining utilization index represent declining active machine value that is relatively less substitution for workmen.

As far as the exact figures of productivity is concerned, the research group could not solve the problem of statistical documentation of the correct measure of production but had to rely upon the data of Forint values. It was found that productivity was increasing

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during the 5 year period by about 30%. To find how much of this could be attributed to mechanization and how much was caused by the increase of the intensity of manual work, a Cobb-Douglas type production function model was used,

$$T = A^{\alpha} \quad B^{(1-\alpha)}$$

Where T = Forint value of production per year

A = Number of productive workers in consecutive years.

B = Active machine value applied in production (yearly)

α = Elasticity of labor

$1-\alpha$ = Elasticity of mechanization (capital)

The calculations showed that $\alpha \approx 0.75$ i.e. mechanization contributed only 25% in the increase of productivity. A multiple correlation analysis resulted about the same figure. Work of the group has been discontinued at this point.

In a parallel program the cost of mechanized mortar mixing and transportation was analysed because these processes were found to be too expensive by the author. (See Table I and remarks). The detailed study sustained the results of the dissertation and proposed to stop further investments in this field.

As far as the author knows in the theoretical field of machine investment policy and related econometric methods no further refinement was made neither was necessary in the construction industry. There was however a certain refinement in data by introducing more realistic price policy in 1958, and thus the outlook for better economic planning will be definitely better in the future.

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